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Engineering & Manufacturing Development (EMD) Phase
Acquisitions &Operations Contract

CAGE NO. 11982

National Polar-Orbiting Operational Environmental Satellite System (NPOESS) 1553 Interface Requirements Document

DATE: February 27, 2004

D34470
REV. A

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Under
Contract No. F04701-02-C-0502

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SUPPLEMENTAL SIGNATURE PAGE FOR APPROVERS OUTSIDE OF MATRIX SYSTEM. (To be filed after cover page of document.)

4-15-04
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Revision/Change Record	For Document No. D34470

Revision	Document Date	Revision/Change Description	Pages Affected
	31Oct 01	Published for PRD Review	All
- - - - -	31 Oct 03	EMD Baseline Release per ECR SS-058, detail changes from PRD version in Excel file	All
A	27 Feb 2004	Updates per NASA & Ball comments and ECR SS-075	1, 4, 8, 9, 10, 11, 14, 18, 21, 22, 32, 33, 37,38 & 40

Outstanding TBRs/TBDs

Item	**Section**	***Section Title***	Description	**Assigned**	**Due Date**
1	1.2.2	Errors Logged	On the BC, the ILL is sized for a maximum of 32 TBR entries as performed by the selected chipset and documented in the ICD.	IA SW– Amy Yu	PDA
2	3.4.7.2.1	Physical Address Reassignment	Table 3.4.7-1 1553 Physical Addresses (TBR)	S/C SE – Wen Chi Chen	PDA
3	3.5.4.3	Telecommand Interval	Each instrument shall be capable of accepting a maximum combined command and memory load rate not to exceed 32 (TBR) packets per second.	S/C SE – Wen Chi Chen	PDA
4	3.7.3	Instrument Combined Data Bus Rate	Table 3.7.3-1 1553 Instrument Total Combined Data Rates (TBR)	FSW- M. Le Rutte & CD&H– B. Thomas	PDA
5	3.4.15.2	Command Enabled 1553 Message	Table 3.4.15-1 Enabled 1553 Message (TBD) – Items #3 through #8	CD&H – Barry Thomas	PDA

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1 SCOPE

This 1553B IRD document defines the functional requirements baseline for the 1553B bus (herein designated “1553B”) interfaces between the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) spacecraft and instruments. This document is comprised of requirements, guidance and clarification. Guidance and clarification are in italics to ensure they are clearly distinguishable for the requirements that must be verified. All of these constitute a formal part of the document with changes to any requiring formal approval.

The Spacecraft Contractor and the Instrument Provider shall each meet their respective interface requirements as defined in this document. The Interface Control Documents (ICD) and the NPOESS General Instrument Interface Document (NGIID) (D31418) are the contractually imposed documents that represent the agreement between the NPOESS spacecraft contractor and the Instrument contractor. This 1553B document takes precedence over these Instrument Interface documents.

This document is intended to cover all requirements and information related to the usage of MIL-STD-1553B and CCSDS in combination for both telecommands and telemetry. The intent is to avoid having instrument contractors assuming the answers to any design decision. This document will be living to the extent that as questions from instrument contractors arise, the answers will be documented here.

Due to the usage of both MIL-STD-1553B and IEEE-1394a-2000 within a common system, this document has been constructed to reduce to complexity that might arise from having portions of the requirements that are common to both by repeating them appropriately within each bus specific interface requirement document.

The overall philosophy is that all instruments are required to completely support the requirements and options contained in MIL-STD-1553B Notice2 as described within this document . All exceptions will require specific waivers and are strongly discouraged. This includes software and hardware. The only exception to MIL-STD-1553B Notice2 and its options are bit ordering. Bit ordering is reversed for compatibility to modern data processing systems including networks.

1.1 Introduction

This is the NPOESS program systems requirements document for 1553B. This specification addresses the implementation of the 1553B data bus interface between designated instruments and the Spacecraft C&DH. It is based on the MIL-STD-1553B serial bus specification with modifications and tailoring that specifically address its use on spacecraft with long life mission goals. When used in conjunction with 1553B standards, it is intended to provide all system requirements and definitions necessary to perform a next level decomposition resulting in compatible design including the system, and, all hardware and software.

1.1.1 1553 Data Bus System Overview

The NPOESS Spacecraft uses the data bus for communication between the spacecraft and the following devices:

- OMPS
- ATMS
- ERBS
- TSIS
- SESS (multiple interfaces)
- GPSOS
- SARSAT – SARR Interface
- ALT
- APS
- SS

1.1.2 Compliance

Each Instrument contractor will obtain spacecraft contractor concurrence for any assumptions regarding 1553B implementation or requirement assumptions or unclear interpretations.

The spacecraft contractor shall maintain this document to include this new information either as a new requirement or explanatory notes.

This document defines and specifies the NPOESS system requirements and first level allocations equivalent to a subsystem where the data bus is its own subsystem.

1.1.3 Identification

This document specifies the system functional and performance requirements for a data bus interfacing the spacecraft and instruments based on the MIL-STD-1553B Serial Multiplex Data Bus specification.

1.1.4 Bus Rate

The 1553B bus uses a serial asynchronous command/response protocol at a fixed transmission rate of 1 Mbps.

1.1.5 Bus Topology

The basic topology for 1553B bus redundancy is shown in Figure 1.1.5-1. This topology provides full data bus media redundancy by using redundant cables and data bus couplers.

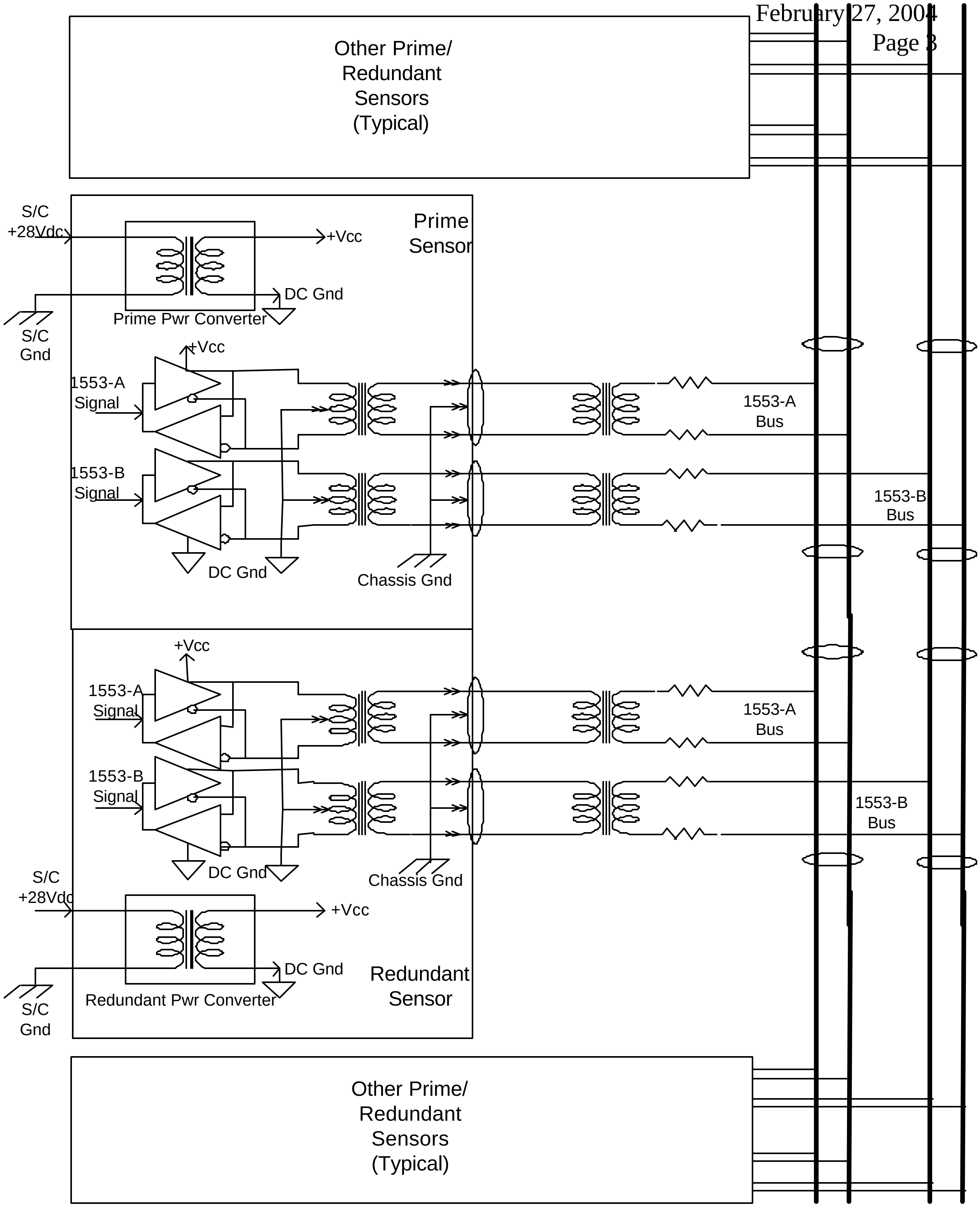


Figure 1.1.5-1 1553 System Topology

1.1.5.1 Total 1553 Throughput

The spacecraft provides multiple buses sufficient to adequately accommodate the total required bandwidth plus margin.

1.1.6 Configuration

All instruments shall be configured as remote terminals (RT) under all modes of operation.

1.1.7 Bus Protocol

Information passed over the 1553B bus includes ground commands, housekeeping data, science data, non-periodic time broadcasts, code/data uploads, and reset commands. Commanding of all 1553B RT nodes is performed via the 1553B data bus. Periodic data is transferred at a predefined rate while a periodic data (e.g., ground commands) is generated in a non-deterministic manner and is therefore transferred whenever required.

1.1.8 Ground Commands and Memory Loads

Ground commands and memory loads are transmitted to the instrument upon completion of packet receipt. Partial packets contained in separate telecommand frames are collected into the whole packets to be forwarded.

1.1.9 Bus Cycle Rate

The spacecraft bus controller (BC) polls each instrument at a maximum rate of 16 Hz (see section 3.7.3). For each bus cycle, there is a minimum of 100 percent margin.

1.2 1553 Errors

1.2.1 Errors Detected

The BC is capable of detecting various errors that occur on the 1553B bus, perform retries where warranted, and log bus errors for inclusion in the spacecraft Housekeeping Data stream. The BC makes use of existing 1553 chip technology for all 1553B communication. As such, there are certain errors that are detected by the chip itself. All errors detected by the chip generate an interrupt for the host CPU to process. Table 1.2.1-1 lists all of the errors detected by the BC along with a brief description of the error.

Table 1.2.1-1 Bus Controller Detected Errors

Error	Description
Error in a RT's response during the Data Wraparound Test	**The data sent to a RT while performing the Data Wraparound Test does not match the data received from the RT. Communications between the BC and RT are suspect.**
Bus cycle overrun	**The BC did not receive the End of Command Block List interrupt for the set of data transfers initiated in the previous bus cycle. Data transfers may still be active.**
1553 Message Error detected by the 1553 chip	**The 1553 chip checks data and control words for proper format according to MIL-STD-1553B. Improperly formatted data or control words will cause the 1553 chip to signal a 1553 Message Error.**

Table 1.2.1-1 Bus Controller Detected Errors	
Error	**Description**
No response from a RT	**The 1553 chip verifies that a RT begins transmitting its Status Word within 14 microseconds of receiving a valid command word. It is important to note that RTs do not transmit their Status Words in response to a BC broadcast.**
Status Word response with the 1553 Message Error bit set to logic "1"	**The 1553 Message Error (ME) bit was set in a RT's 1553B Status Word. A RT will set its ME bit when an invalid data 1553B word is received, an illegal command is received, or an error in the data word count is detected.**
Status Word response with the Busy bit set to logic "1"	**The Busy bit was set in a RT's 1553B Status Word. An RT uses this bit to indicate to the BC that it cannot comply with the command received. The RT cannot move data to or from the 1553B bus.**
Data Overrun detected by the 1553 chip	**The 1553 chip was unable to access 1553B shared memory within the time allowed. This would indicate that the host processor was accessing the memory thereby locking out the 1553 chip.**
Illegal Command Error detected by the 1553 chip	**The 1553 chip detected improperly formatted command blocks. This includes incorrectly formatted RT-RT command blocks.**
Retry Failure detected by the 1553 chip	**The indicated number of programmed retries has failed.**

1.2.2 Errors Logged

The BC also maintains an Interrupt Log List (ILL) that allows the host CPU to review interrupts in chronological order. Each entry in the ILL contains an Interrupt Status Word, a pointer to the Command Block causing the interrupt, and a pointer to the next entry in the list. On the BC, the ILL is sized for a maximum of 32 TBR entries as performed by the selected chipset and documented in the ICD.

If more interrupts are generated during the course of a 1553B bus cycle, the BC will either overwrite the last entry in the list, or, circulate back to the first entry in the list and overwrite that entry, as performed by the selected chipset and documented in the ICD.

1.2.3 1553 Message Error Retry

When a 1553 Message Error is detected (via the RT Status Word or by the BC), an RT is busy (as indicated by its Status Word), or a RT fails to respond, the BC directs one retry of the 1553 Message transfer on the alternate bus.

The BC provides 1553B bus error telemetry that reports if a 1553 Message transfer retry was unsuccessful (i.e., retry failure), if the bus cycle was overrun, the number of erroneous RT responses (during the Data Wraparound Test), the number of RT response time-outs, the number of 1553 Message Errors and the number of BC detected 1553B fault interrupts (Data Overrun and Illogical Command).

1.2.4 Erroneous Received 1553 Message

Data contained within an erroneously received 1553 Message shall be discarded.

2 APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, shall form a part of this document to the extent specified herein. When no issue is specified, the latest version of the document shall apply.

Design Assumptions: Where these documents are not explicit enough to perform a portion of the system, hardware and software designs, the spacecraft contractor will be consulted.

Waivers, exceptions and deviations to this document will not be approved.

The spacecraft contractor shall be the mediator for any unclear, unspecified, or conflicting requirement.

2.1 Government Documents

The following documents of the exact issue shown form a part of this 1553B IRD to the extent specified herein.

In the event of conflict between the documents referenced herein or other documents referencing this document and the contents of this specification, this document shall be considered a superseding requirement.

2.1.1 Specifications

None

2.1.2 Standards

MIL-STD-461E	(Tailored) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-1553B	Notice 2, Military Standard Digital Time Division Command/Response multiplex Data Bus

2.2 Non-government Documents

a. The following documents of the exact issue shown form a part of this 1553B IRD to the extent specified herein.

b. In the event of conflict between the documents referenced herein or other documents referencing this document and the contents of this specification, this document shall be considered a superseding requirement.

2.2.1 Specifications

D31418	NPOESS General Instrument Interface Document (NGIID)for National Polar-Orbiting Operational Environmental Satellite System (NPOESS)
D35853	APID, VCID and Data Path Document

2.2.2 Standards

2.3 Reference Documents

2.3.1 Specifications

None

2.3.1 Standards

CCSDS 301.0-B-2	Consultative Committee for Space Data Systems (CCSDS) Recommendation for Time Code Formats, Blue Book, 1990
CCSDS 701.0-B-2	Advanced Orbiting Systems, Networks and Data Links, Blue Book, November 1992

3 1553 ELECTRICAL INTERFACE REQUIREMENTS

All instruments shall be configured as remote terminals (RT) under all modes of operation.
All 1553B nodes shall be compliant with MIL -STD-1553B, Notice 2 using the transformer coupling option for the bus connection.
All requirements shall be met at the receiving end of the electrical interface.

3.1 Serial-Digital Data Formatting

3.1.1 Bit Numbering

All multiple bit sequences shall count bits beginning with bit 0[a].

3.1.2 Octet Structure

All data shall be modulo based upon the smallest object, an Octet, comprised of eight (8) binary bits to be formatted as MSB (bit zero) first and shall be pictorially represented as shown in Table 3.1.2-1.

Table 3.1.2-1 Octet Representation							
Bit Zero MSB	1	2	3	4	5	6	Bit Seven LSB

3.1.3 Octet Numbering Convention and Nomenclature

The transmission order of bits within an Octet and the relative ordering of octets within a word shall be submitted for transmission 'Big Endian[b].
When applied to networking, this is called 'Network Byte Order'.

- Bit 0 of an N-bit$_{(\text{modulo 8bits})}$ value shall be the Most Significant Bit (MSB).
- Bit N-1 of an N-bit$_{(\text{modulo 8bits})}$ value shall be the least significant bit.

The octet containing bits 0-7 shall be transmitted first, followed by the next sequential octet until all octets are transmitted.

3.1.4 Bit Sequencing

For serial data, the most significant bit (MSB, i.e. bit zero) shall be sent first.

3.1.5 Data Segment Sequencing

For data segmentation, the segments shall be sent ordered most significant segment first

3.1.6 Spare Bits

All "spare" bits within a CCSDS packet data should be permanently set to value "zero".

3.1.7 CCSDS Packet Boundaries

All CCSDS packets shall have the total number of octets, including all headers and data, be an even number.

---

[a] Bit Numbering convention is different than 1553 but compatible with data from the 1394 bus.

[b] Note also that 'Big Endian' byte ordering is NOT what some machines (notably the 80x86 class of machines) use internally.

3.1.8 Byte/Octet Padding

No padding shall be appended within the CCSDS packet to fix the length of a CCSDS packet that contains variable length data field.

3.1.8.1 CRC and Checksums

3.1.8.1.1 Telecommands

The usage of CRC or checksums for commands shall be at the discretion of the instrument provider.
The spacecraft contractor discourages the use of these codes for general commands. The spacecraft will not process CRC or checksums for instruments. Instrument memory and table loads may want to use checksum.

3.1.8.1.2 Telemetry

CRC and checksums shall not be implemented.

3.2 Fault Tolerance

No single failure in the 1553 bus electrical interface circuit on either the instrument side of the interface or the spacecraft bus side of the interface shall cause the instrument to lose the capability to communicate with both the primary and the redundant 1553 buses via each functionally distinct RT.

3.2.1 Transformer Isolation

Each RT shall be individually transformer coupled as shown in Figure 1.1.5-1 to both the primary and the redundant 1553 buses.
The interface design shall implement a long stub match system of transformers.

3.2.1.1 Instrument Unit Fault

A fault anywhere within the instrument or the data bus shall be precluded from propagating to redundant portions of the instrument or to the data bus.

3.3 1553 Message Formatting

3.3.1 Telemetry Formatting

Telemetry packets shall all be formatted as CP_PDU source packets per CCSDS 701.0-B-2 and the figures for the specific packet types shown in Table 3.3.1-1. *Table 3.3.1-1 is intended to be superset of the formats that might be used. It does not require that all formats be used. If there are additional format type desired they may be added to the ICD following agreement by the spacecraft contractor who may also choose to add the new type to the superset listed in the IRD.*
Table 3.3.1-1 includes telemetry packet types that may consist of segmented CCSDS packets, and that the maximum size of each CCSDS packet is as defined in Table 3.3.2-1. If a packet does not have a segmented format shown it is intended to only be standalone.

3.3.1.1 Test Packets

Test packets shall be a stand alone 256 byte CCSDS formatted packet containing CC_{hex} for each byte of data generated continuously by the instrument processor and sent to the bus controller at science data packet frequency when commanded by the spacecraft.

3.3.1.2 Memory Dump Packets

Memory dump packets shall consist of the contents of the commanded range of memory or processor register dump.

3.3.1.3 Engineering Packets

Engineering packets shall consist of all engineering data required to meet specified science data processing performance such that the combination of science data and engineering data is, without excess, sufficient to achieve specified performance.

3.3.1.4 Housekeeping Packets

Housekeeping packets shall consist of information relating to the state of health of the instrument but not including data contained in any other packet.

3.3.1.5 Dwell Packets

Dwell packets shall consist of the resulting data of commanded housekeeping or engineering data over-sampling to obtain increased bandwidth knowledge for diagnostic purposes.

3.3.1.6 Calibration Packets

Calibration packets shall consist of resulting data from instrument calibration, alignment or other precision enhancing actions, used to compensate or otherwise reduce science and/or engineering data uncertainties.

3.3.1.7 LEO&A Packets

LEO&A packets shall contain the bare minimum housekeeping data necessary for management of the instrument when the spacecraft normal telemetry stream is not functioning due to emergency conditions.

3.3.1.8 Diagnostic Packets

Diagnostic packets shall contain data for instrument diagnostic purposes during normal or diagnostic mode as required by the instrument.

3.3.1.9 Science Packets

Science packets shall consist of instrument measurement and observation data, whether processed or raw, such that the combination of science data and engineering data is, without excess, sufficient to achieve specified performance.

3.3.1.10 Telemetry Monitor Packet

Telemetry Monitor packets shall contain the bare minimum data necessary to be monitored by the spacecraft requiring prescribed actions by the spacecraft specified in the ICD.

Table 3.3.1-1 1553 Telemetry Types and Packet Sizes

User Spacecraft /Ground	Telemetry Packet	Packet Length in CCSDS octets Including Headers	Required/ Optional	Segment or Standalone	Figure
SC	Test Packets[a]	Maximum 256	Required	Standalone	Figure 3.3.3-4 Non-Segmented Mission Data & Telemetry Packet—Standalone Segment Figure 3.3.3-5
Ground	Memory Dump Packet	Maximum 1024	Optional	Both	Figure 3.3.3-1 Figure 3.3.3-2 Figure 3.3.3-3
Ground	Engineering data packets	Maximum 256	Required	Both	Figure 3.3.3-1 Figure 3.3.3-2 Figure 3.3.3-3
Ground	Housekeeping packets	Maximum 256	Required	Both	Figure 3.3.3-1 Figure 3.3.3-2 Figure 3.3.3-3
Ground	LEO&A Housekeeping packets	Maximum 32	Required	Standalone	Figure 3.3.3-4 Non-Segmented Mission Data & Telemetry Packet—Standalone Segment Figure 3.3.3-5
Ground	Calibration packets	Maximum 256	Optional	Both	Figure 3.3.3-1 Figure 3.3.3-2 Figure 3.3.3-3
Ground	Dwell	Maximum	Optional	Both	Figure 3.3.3-1

[a] The Data field shall be "CCCC$_{HEX}$".

	Packets	**256**			**Figure 3.3.3-2 Figure 3.33-3**
Ground	**Diagnostic packets**	**Maximum 256**	**Optional**	**Both**	**Figure 3.3.3-1 Figure 3.3.3-2 Figure 3.3.3-3**
Ground	**Science packets (Raw or Processed)**	**Maximum 1024**	**Required**	**Both**	**Figure 3.3.3-1, Figure 3.3.3-2, Figure 3.3.3-3.**
Spacecraft	**Telemetry monitoring packets**	**Maximum 32**	**Optional**	**Standalone**	**Figure 3.3.3-4 Non-Segmented Mission Data & Telemetry Packet—Standalone Segment Figure 3.3.3-5**

3.3.2 Telecommand Formatting

Telecommand packets shall all be formatted as CP_PDU source packets per CCSDS 701.0-B-2 and the figures for the specific packet types shown in Table 3.3.2-1.

Table 3.3.2-1 Telecommand Types and Packet Sizes

Source Spacecraft/ Ground	Tele-command Packet	Packet Length in CCSDS octets Including Headers	Required/ Optional	Segment or Standalone	Figure
Spacecraft	Time of Day Broadcast	Fixed 14 Minimum	Required	Standalone	Figure 3.3.3-10
Both	Command	Maximum 256	Required	Both	Figure 3.3.3-6 Figure 3.3.3-7 Figure 3.3.3-8 Figure 3.3.3-9
Both	Memory Load	Maximum 1024[a]	Required	Both	Figure 3.3.3-6 Figure 3.3.3-7 Figure 3.3.3-8 Figure 3.3.3-9

[a] The maximum packet size is defined by the source of the packet. Ground packets must not exceed 1016 CCSDS octets in size due to the telecommand frame restrictions. SC sourced packets may be allowed to reach 1024 CCSDS octets.

3.3.3 Broadcast Formatting

All 1553 RT's shall be capable of receiving broadcast 1553 Message.

First Source Packet of a Segmented Message (PSC=01)										
Primary Header							Secondary Header			DATA FIELD
Packet Identification				Packet Sequence Control (PSC)		Packet Length				
000	0	1	XXXXXXXXXXX (11bits)	01	XXXXXXXXXXXXXX (14bits)	XXXXXXXXXXXXXXXX (16bits)	8 Octets (64 bits)	XXXXXXXX (8bits)	00000000 (8bits)	Variable Octets
Fixed by CCSDS	Type is Telemetry	Secondary Header	APID Assigned to this data	Packet	Sequence # 00 = Middle 01 = First 10 = Last 11 = Standalone	Length of this specific packet in octets = Secondary Header plus Data Fields-1	CCSDS CDS Level 1 Time of Day Start of data	PSC Type = 01 Number of Packet Segments - 1	Spare	

Figure 3.3.3-1 Segmented Mission Data &Telemetry Packet – First Segment

Middle Source Packet of a Segmented Packet Set (PSC=00)							
Primary Header							DATA FIELD
Packet Identification				Packet Sequence Control (PSC)		Packet Length	Data
000	0	0	XXXXXXXXXXX (11bits)	00	XXXXXXXXXXXXXX (14bits)	XXXXXXXXXXXXXXXX (16bits)	Variable Octets
Fixed by CCSDS	Type is Telemetry	Secondary Header	APID Assigned to this data	Packet	Sequence # 00 = Middle 01 = First 10 = Last 11 = Standalone	Length of this specific packet in octets = Secondary Header plus Data Fields-1	

Figure 3.3.3-2 Segmented Mission Data & Telemetry Packet – Middle Segment

Last Source Packet of a Segmented Packet Set (PSC=10)							
Primary Header							DATA FIELD
Packet Identification				Packet Sequence Control (PSC)		Packet Length	Data
000	0	0	XXXXXXXXXXX (11bits)	**10**	XXXXXXXXXXXXXX (14bits)	XXXXXXXXXXXXXXXX (16bits)	Variable Octets
Fixed by CCSDS	Type is Telemetry	Secondary Header	APID Assigned to this data	Packet	Sequence # 00 = Middle 01 = First 10 = Last 11 = Standalone	Length of this specific packet in octets = Secondary Header plus Data Fields-1	

Figure 3.3.3-3 Segmented Mission Data & Telemetry Packet – Last Segment

Standalone Never Segment Packet (PSC=11)							
Primary Header							DATA FIELD
Packet Identification				Packet Sequence Control (PSC)		Packet Length	Data
000	0	0	XXXXXXXXXXX (11bits)	**11**	XXXXXXXXXXXXXX (14bits)	XXXXXXXXXXXXXXXX (16bits)	Variable Octets
Fixed by CCSDS	Type is Telemetry	Secondary Header	APID Assigned to this data	Packet	Sequence # 00 = Middle 01 = First 10 = Last 11 = Standalone	Length of this specific packet in octets = Secondary Header plus Data Fields-1	

Figure 3.3.3-4 Non-Segmented Mission Data & Telemetry Packet – Standalone SegmentFigure

Only Source Packet of a Non-segmented Packet (PSC=11)								
Primary Header							Secondary Header	DATA FIELD
Packet Identification				Packet Sequence Control (PSC)		Packet Length		
000	0	1	XXXXXXXXXXX (11bits)	**11**	XXXXXXXXXXXXXX (14bits)	XXXXXXXXXXXXXXXX (16bits)	8 Octets	Variable Octets
Fixed by CCSDS	Type is Telemetry	Secondary Header	APID Assigned to this data	Packet	Sequence #	Length of this specific packet in octets = Secondary Header plus Data Fields-1	CCSDS CDS Level 1 Time of Day Start of data	
				00 = Middle 01 = First 10 = Last 11 = Standalone				

3.3.3-5 LEO&A, Telemetry Monitor and Test Telemetry Packet Format

First Source Packet of a Segmented Telecommand Packet Set (PSC=01)									
Primary Header							Secondary Header		DATA FIELD
Packet Identification				Packet Sequence Control (PSC)		Packet Length			
000	1	1	XXXXXXXXXXX (11bits)	**01**	XXXXXXXXXXXXXX (14bits)	XXXXXXXXXXXXXXXX (16bits)	XXXXXXXX (8bits)	00000000 (8bits)	Variable Octets
Fixed by CCSDS	Type is Command	Secondary Header	APID Assigned to this data	Packet	Sequence # 00 = Middle 01 = First 10 = Last 11 = Standalone	Length of this specific packet in octets = Secondary Header plus Data Fields-1	PSC Type = 01 Number of Packet Segments - 1	Spare	

Figure 3.3.3-6 Telecommand Segmented Data Packet – First Segment

Middle Source Packet of a Segmented Telecommand Packet Set (PSC=00)							
Primary Header							DATA FIELD
Packet Identification				Packet Sequence Control (PSC)		Packet Length	
000	1	0	XXXXXXXXXXX (11bits)	**00**	XXXXXXXXXXXXXX (14bits)	XXXXXXXXXXXXXXXX (16bits)	Variable Octets
Fixed by CCSDS	Type is Command	Secondary Header	APID Assigned to this data	Packet	Sequence # 00 = Middle 01 = First 10 = Last 11 = Standalone	Length of this specific packet in octets = Secondary Header plus Data Fields-1	

Figure 3.3.3-7 Telecommand Segmented Data Packet – Middle Segment

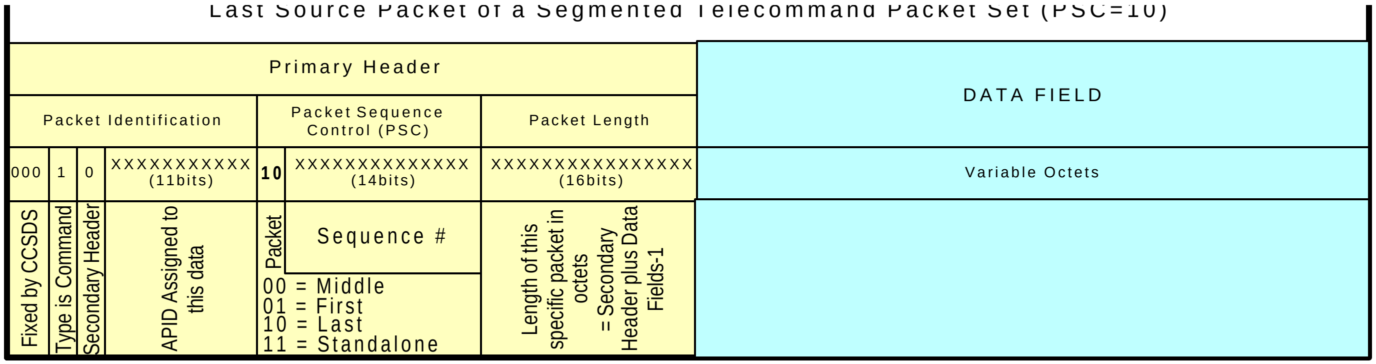


Figure 3.3.3-8 Telecommand Segmented Data Packet – Last Segment

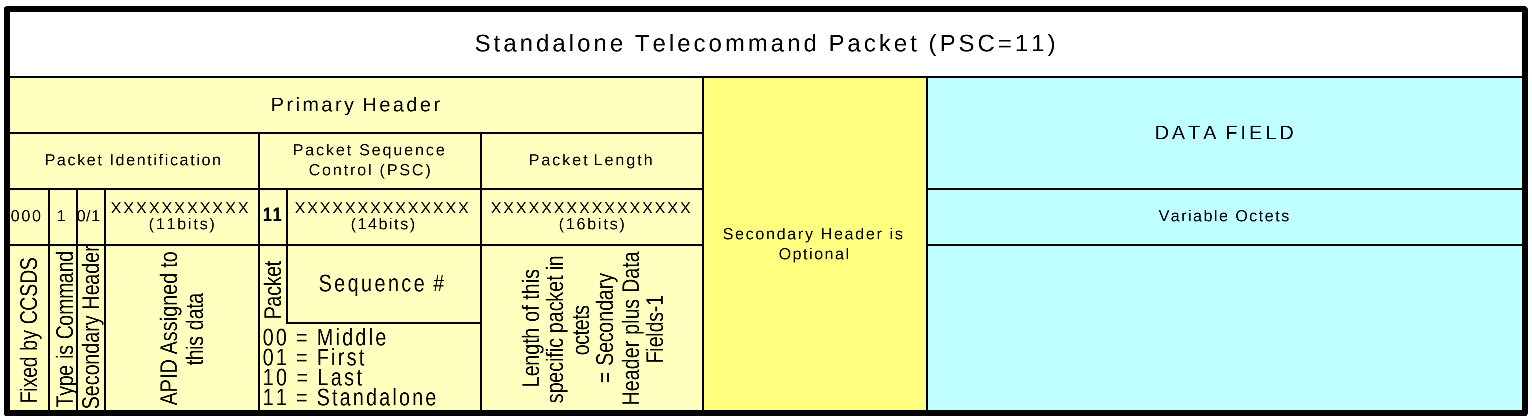


Figure 3.3.3-9 Telecommand Non-Segmented Data Packet – Standalone Segment

14 Octets + Data Field if any								
Primary Header (6 octets)							Secondary Header	Data
Packet Identification				Packet Sequence Control (PSC)		Packet Length	Time of Day	Unused
000	0	1	XXXXXXXXXXX (11bits)	11	XXXXXXXXXXXXXX (14bits)	XXXXXXXXXXXXXXXX (16bits)	8 Octets	Unused
Fixed by CCSDS	Type is Telemetry	Secondary Header	APID Assigned to this data	Packet	Sequence #	Length of this specific packet in octets = Secondary Header plus Data Fields-1	CCSDS CDS Level 1 Time of Day Start of data	Unused
				00 = Middle 01 = First 10 = Last 11 = Standalone				

Figure 3.3.3-10 Broadcast Time of Day Packet Format

3.4 Operation

3.4.1 Bus Functions

The 1553 bus shall communicate the following:

a. Spacecraft to instrument transfers consisting of:

- Real time commands; commands from the ground or generated on-board
- Stored commands; commands stored by the spacecraft for later execution. Instrument stored commands shall be executed internal to the instrument and shall be received as memory loads.
- Memory loads; memory loads shall be from either the ground or the spacecraft. *They will arrive as whole CCSDS packets even when the load is segmented.*
- Time code data.

b. Instrument to spacecraft transfers consisting of:

- Engineering data
- Housekeeping data
- Calibration data
- Mission science data; data as defined by the instrument related to observations
- Diagnostic data; data specifically generated to diagnose a suspected problem
- Dwell data; data produced by a commanded dwell mode to super-sample a specific subset of information
- Telemetry monitoring data

3.4.1.1 Segmented Uplink 1553 Messages

3.4.1.1.1 Uplink CCSDS Packet Set (CPS) Size

Instruments shall not require a single CCSDS Packet Set to be greater than 40,760 bits (one-tenth (1/10) of the minimum uplink total bandwidth opportunity which is defined to be ½ the framed uplink data rate over a six (6) minute period where framing efficiency is 1019/1024).

$$\left[\frac{\dfrac{\left(1019/1024\right) \times 125{,}000 \times 6}{2}}{10} \right] \approx 37316 \ bits \approx 5 \ packets \cong L \leq 40760 \text{ bits}$$

3.4.1.1.2 Partial Packets

The spacecraft shall never forward to an instrument an incomplete CCSDS Packet.

3.4.1.1.3 Partial CCSDS Packet Sets

The spacecraft shall forward to the instrument all CCSDS Packets as they are received without regard to CCSDS Packet Segmentation.

3.4.1.1.4 Large Uplink Protocol

a. Instruments shall detect the start of a new CCSDS Packet Set by Packet Sequence Control (PSC) beginning with binary “01”.
b. Instruments shall be capable of accepting uplink Data Sets, including Segmented commands and Segmented loads where there may be other commands and time delays as long as one (1) second inserted between the CCSDS Packet Segments that comprise the CCSDS Packet Set.
c. Instruments shall detect a time delay greater than one (1) second between receipt of CCSDS Packet Segments and as a result terminate the load or command.
d. All subsequent CCSDS Packets part of a terminated CCSDS Packet Set shall be dropped by the instruments without execution.

3.4.2 Bus Type

The 1553 bus shall be dual standby redundant and fully comply with the requirements of MIL -STD-1553BNotice 2 (Applicable Document 2.6), all sections.
Note: Additional requirements are specified wherever necessary to select MIL-STD-1553B options and to eliminate ambiguities.

3.4.3 Bus Configuration

The spacecraft shall provide the Bus Controller (BC) and possibly one or more remote terminals (RT) to send data to and collect data from the instrument.
All 1553 Interfaces shall be dual redundant.
All instrument 1553 interfaces shall be defined as RT(s) to receive data from and send data to the spacecraft upon request.

3.4.3.1 Number of Functionally Distinct Instrument Remote Terminals

Each instrument using the 1553 data bus shall have one and only one dual redundant RT interface coupled to the data bus.

3.4.4 Electrical Interface

Each electrical interface to the 1553 bus shall comply with the requirements of MIL-STD-1553B..

3.4.5 Mode Codes

The instrument RT shall be capable of supporting all mode codes per Table 3.4.5-1 .

Table 3.4.5-1 Mode Code Implementation Requirement			
Mode Code	Function	Req'd	Implementation Requirement
00000	**Dynamic Bus Control**	**N**	**Ignored/not supported**
00001	**Synchronize**	**Y**	**Shall be implemented in hardware and nothing shall preclude later use by software as required by MIL-STD-1553B**
00010	**Transmit Status Word**	**Y**	**As required by MIL-STD-1553B**
00011	**Initiate Self Test**	**Y**	**Shall result in a status word per Table 3.4.6-1.**
00100	**Transmitter Shutdown**	**Y**	**As required by MIL-STD-1553B**
00101	**Override Transmitter Shutdown**	**Y**	**As required by MIL-STD-1553B**
00110	**Inhibit Terminal Flag Bit**	**Y**	**As required by MIL-STD-1553B**
00111	**Override Inhibit Terminal Flag Bit**	**Y**	**As required by MIL-STD-1553B**
01000	**Reset Remote Terminal**	**Y**	**Shall Reset the logic in RTs**
01001	**Reserved**	**N**	**Ignored**
½	½	**N**	½
½	½	**N**	½
–	–	**N**	–
01111	**Reserved**	**N**	**Ignored**
10000	**Transmit Vector Word**	**N**	**Ignored**
10001	**Synchronize with data word**	**Y**	**Shall be implemented in hardware and nothing shall preclude later use by software as required by MIL-STD-1553B**
10010	**Transmit Last Command**	**Y**	**As required by MIL-STD-1553B**
10011	**Transmit BIT Word**	**N**	**Ignored**
10100	**Selected Transmitter Shutdown**	**N**	**As required by MIL-STD-1553B (BC to Single RT and BC to Multiple RT's)**
10101	**Override Selected Transmitter Shutdown**	**N**	**As required by MIL-STD-1553B (BC to Single RT and BC to Multiple RT's)**
10110	**Reserved**	**N**	**Ignored**

3.4.6 Status Word

During the 1553 bus operation, the status bits in the status word transmitted by the instrument RT shall be implemented in accordance with Table 3.4.6-1.

Table 3.4.6-1 Status Word Implementation Requirement			
Status Bits	Function	Req'd	MIL-STD-1553B Paragraph Numbers Or Implementation Requirements
1 – 3	Synch	Y	As required by 4.3.3.5.1.1
4 –8	RT Address	Y	As required by 4.3.3.5.1.2

Table 3.4.6-1 Status Word Implementation Requirement

Status Bits	Function	Req'd	MIL-STD-1553B Paragraph Numbers Or Implementation Requirements
9	1553 Message Error	Y	As required by 4.3.3.5.3.3
10	Instrumentation	N	Shall be set to logic zero as required by MIL-STD-1553B
11	Service Request	N	Shall be reset to logic zero as required by MIL-STD-1553B
12 – 14	Reserved	N	Reset to logic zero as required by MIL-STD-1553B
15	Broadcast Command Received	Y	Shall be set to logic one to indicate that the last command received was a broadcast command or logic zero to indicate that the last command was not a broadcast command.
16	Busy	Y	As required by 4.3.3.5.3.8.
17	Subsystem Flag	Y	Shall be set to logic one to indicate that an internal failure exists in the RT or that the requested data may not be valid. RT shall use this bit to indicate detectable internal failures or conditions resulting in the potential of incorrect or corruption of MIL-STD-1553B data.
18	Dynamic Bus Control Accept	N	Shall not be implemented and shall be permanently reset to logic zero.
19	Terminal Flag	Y	Shall be set to logic one to indicate RT fault as a result of self-test. Shall be permanently reset to logic zero if RT does not contain any self-test feature.
20	Parity	Y	As required by MIL-STD-1553B. Odd parity over the preceding 16 bits.

3.4.7 RT Addresses

3.4.7.1 Physical Address

Each RT shall contain a fixed and unique physical address to differentiate the data on the data bus intended for its consumption.

3.4.7.2 RT Physical Address Assignment

Instrument RT physical address assignment shall be as listed in Table 3.4.7-1.

3.4.7.2.1 Physical Address Reassignment

The RT address shall be externally selectable without disassembly of the instrument.

Table 3.4.7-1 1553 Physical Addresses (TBR)

RT Unit	Address
	00
CERES	01
OMPS	02
ERBS	03
TSIS	04
GPSOS	05
ALT	06
	07
APS	08
I SS	09
SARSAT--SARR	10
SESS	11
ATMS	12
	13
	14
	15

RT Unit	Address
	16
	17
	18
	19
	20
	21
	22
	23
	24
	25
	26
	27
	28
	29
Bus Monitor	30
Broadcast 1553 Messages	31

3.4.7.3 APIDs

Each RT physical address shall support multiple APIDs that uniquely identify specific unit application processes.
All APIDs, except for the one fixed for ground command, shall be reprogrammable prior to launch without instrument removal from the spacecraft. The initial values for satellite APIDs shall be as listed in APID, VCID and Data Path Document D35853.

3.4.8 RT Sub-address Assignment

Assignment of instrument RT receive sub-addresses and transmit sub-addresses shall be as tabulated in Table 3.4.8-1 and Table 3.4.8-2 respectively.

Table 3.4.8-1 Instrument RT Receive Sub-address Assignment

RT Receive Sub-address	Data/Function
00	Mode Code
01	Reserved
02	Reserved
03	**Reserved**
04	**Reserved**
05	Instrument Commands or Memory Loads
06	Instrument Commands or Memory Loads
07	Instrument Commands or Memory Loads
08	Instrument Commands or Memory Loads

Table 3.4.8-1 Instrument RT Receive Sub-address Assignment	
RT Receive Sub-address	Data/Function
09	Instrument Commands or Memory Loads
10	**Instrument Commands or Memory Loads**
11	Instrument Commands or Memory Loads
12	Instrument Commands or Memory Loads
13	Instrument Commands or Memory Loads
14	Instrument Commands or Memory Loads
15	Instrument Commands or Memory Loads
16	Instrument Commands or Memory Loads
17	Instrument Commands or Memory Loads
18	Instrument Commands or Memory Loads
19	Instrument Commands or Memory Loads
20	Instrument Commands or Memory Loads
21	Time Code Data
22	Time Code Data
23	Reserved
24	Reserved
25	Reserved
26	Reserved
27	Reserved
28	Instrument Reset Command
29	End of Data Transfer Cycle
30	Data Wrap Around
31	Mode Code

Table 3.4.8-2 Instrument RT Transmit Sub-address Assignment	
RT Transmit Sub-address	Data/Function
00	Reserved
01	Reserved
02	Reserved
03	Reserved
04	Reserved
05	Data Packets
06	Data Packets
07	Data Packets
08	Data Packets
09	Data Packets
10	Data Packets
11	Data Packets
12	Data Packets
13	Data Packets

Table 3.4.8-2 Instrument RT Transmit Sub-address Assignment

RT Transmit Sub-address	Data/Function
14	Data Packets
15	Data Packets
16	Data Packets
17	Data Packets
18	Data Packets
19	Data Packets
20	Data Packets
21	Reserved
22	Reserved
23	Reserved
24	Reserved
25	Reserved
26	Reserved
27	Reserved
28	Reserved
29	Data Readiness Indicator
30	Data Wrap Around
31	Reserved

3.4.9 Data Wrap Around

The BC shall periodically perform a Data Wraparound Test to selected, enabled RT's.

Note: The Data Wraparound Test is used to test the data flow through a RT's transceiver (1553B hardware), initial subsystem interface (memory buffers), and the data bus media (cabling and bus couplers).

The instrument RT shall implement Data Wrap Around function defined in Section 30.7, MIL-STD-1553B using #30 receive and transmit sub-addresses .

3.4.9.1 Data Wrap Around Test Frequency

The data wraparound test shall occur at a rate of 0 to 16 per second where the maximum is defined by the polling rate.

3.4.9.2 Data Wrap Around Test Pattern

The data pattern used for the Data Wraparound Test shall be a single 16-bit word.

Note: The BC ping-pongs between two 16-bit data patterns on alternating cycles of the Data Wraparound Test to a given RT. When the data pattern transmitted to a given RT does not match the data pattern received from it, the BC indicates that communication between it and the RT is suspect.

3.4.10 Automatic Retry

Communication with each instrument shall start on the primary 1553 bus.

The spacecraft shall retry once on the redundant 1553 bus in the event of communication errors or problems.

There shall be no retry for broadcast.

The capability to re-designate the primary and the redundant 1553 buses in orbit via ground commands shall be provided by the spacecraft.

The spacecraft shall report RT error counts and retry failure counts to the ground.

3.4.11 Deleted

3.4.12 Remote Terminal Self Test

The instrument RT(s) shall be capable of performing self-testing by producing the status word in Table 3.4.6-1.

3.4.13 Illegal Command monitoring By Instrument RT

The instrument RT shall monitor and reject illegal bus commands.

3.4.14 Instrument Reset

The spacecraft shall use an instrument command to reset an instrument remote terminal to reinitialize communication.

Instrument Reset commands shall not be encapsulated in CCSDS packets.

3.4.14.1 Instrument Reset Format

An instrument Reset command shall be a single 16-bit word that is sent to the instrument on receive subaddress 28 in Table 3.4.8-1.

3.4.14.2 Instrument Reset Contents

An instrument Reset command word shall contain a code directing a soft reset of the instrument per Table 3.4.14-1.

Table 3.4.14-1 Instrument Reset Codes

Function	Word Value
Soft Reset	`1111 1111 0000 0000` (FF00$_{Hex}$)
No-op	All Others

3.4.14.2.1 Soft Reset

An instrument soft reset shall cause the remote terminal and associated processor to restart communications services by reinitializing all remote terminal variables and registers.

3.4.15 1553 Bus Initialization

The BC shall initialize with all instrument bus 1553 Messages disabled.

3.4.15.1 Autonomous 1553 Message Enabling

The spacecraft shall contain stored sequences that enable 1553 Messages when instrument power is turned on.

3.4.15.1.1 1553 Messages Enabled Autonomously

Table 3.4.15-1 defines the 1553 Message traffic for the bus and includes the 1553 Message ID, transmitting and receiving unit, sub-addresses, 1553 Message frequency, and additional comments where warranted.

3.4.15.2 Command Enabled 1553 Message

Additional 1553 Message are enabled by ground commands.
This is done to prevent the BC from initiating communication with a RT that is not ready to communicate (e.g., a RT that is powered off).

Table 3.4.15-1 Enabled 1553 Message (TBD)

Item	1553 Message Id	Transmit Unit	Receive Unit	Freq (Hz)	Size (Wd)	Comment
1	General Purpose 1553 Message	BC	RT	8	128 max	The receive unit, receive subaddress, and 1553 Message size are determined by the command received.
2	Time Code	BC	Broadcast	1	48	Within 100-900 ms before the Time of Day pulse
3	Data Wraparound	BC	RT	0-16	1	
4	Data Wraparound	RT	BC	0-16	1	Same time as above Data Wraparound Test.
5	Data Ready Indicator	RT	BC	TBD	1	
6	Data	RT	BC	TBD	512 max	When DRI changes.
7	End of Data Transfer Cycle	BC	RT	TBD	[3] 7	After the above transfer has occurred.

Table 3.4.15-1 Enabled 1553 Message (TBD)

Item	1553 Message Id	Transmit Unit	Receive Unit	Freq (Hz)	Size (Wd)	Comment
8	Command / Memory Load Telecommand Packet	BC	RT	TBD	512 max	As needed.

3.5 Instrument Telecommands (Commands and Memory Loads)

The spacecraft bus controller (BC) shall control the transfer commands and memory loads to the instrument by conducting a sequence of BC-to-RT transfers defined in Section 4.3.3.6.2 of MIL-STD-1553B using specified instrument RT receive sub-addresses and the following protocol:

3.5.1 Packetization for Commands and Memory Loads

Unless otherwise specified, all commands and memory loads delivered to the instrument shall be formatted in accordance with the CCSDS AOS packet defined in CCDS 701.0-B-2.

3.5.2 Command and Memory Load Packet Length

A single command or memory load packet shall be per section 3.3.2 (and the note therein), or shorter.

3.5.3 Documentation

All instrument commands and memory load packets shall be documented in the ICD.

3.5.4 Commands and Memory Loads Transfer

The spacecraft shall deliver the following data to the specified instrument RT receive sub-addresses by conducting single BC to RT Transfers defined in Section 4.3.3.6.1, or single RT to RT Transfers (from a spacecraft RT to an instrument RT) defined in Section 4.3.3.6.3 of MIL-STD-1553B.

3.5.4.1 Command and Memory Load Sub-addresses

Command and memory load sub-addresses shall be as listed in Table 3.4.8-1.

3.5.4.1.1 First Subaddress

Each packet shall start at the first Instrument Command or Memory Load subaddress in Table 3.4.8-1.

3.5.4.1.2 Last Subaddress

No packet shall exceed the total number of Instrument Command or Memory Load subaddresses in Table 3.4.8-1.

3.5.4.2 Telecommand Maximum Rate

At predefined intervals, the maximum to be documented in the ICD, the BC shall transfer any currently received commands from the spacecraft on-board computer or ground terminal.

3.5.4.3 Telecommand Interval

Each instrument shall be capable of accepting a maximum combined command and memory load rate not to exceed 32 (TBR) packets per second.

3.5.5 Telecommand APIDs

Each instrument shall have four (4) unique APIDs allocated for spacecraft and ground commands (2) and memory loads (2).

3.5.5.1 Command APIDs

There shall be two (2) APIDs for commands.
One APID shall define a command from the ground.

- The APID assigned to ground commands shall be per APID, VCID and Data Path Document D35853.
- The APID assigned to ground commands shall not be alterable.

The other APID shall define a command from the spacecraft.

3.5.5.2 Memory Load APIDs

There shall be two (2) APIDs for memory loads.

a. One APID shall define a memory load from the ground.
b. The other APID shall define a memory load from the spacecraft.

3.5.5.3 Commands and Memory Loads

3.5.5.3.1 Spacecraft Commands and Memory Loads

Instruments shall be capable of receiving “near simultaneously” spacecraft generated commands, and ground generated memory loads.

3.5.5.3.2 Ground Commands and Spacecraft Memory Loads

Instruments shall be capable of receiving “near simultaneously” ground terminal generated commands and spacecraft generated memory loads.

3.5.5.3.3 Spacecraft Commands and Ground Commands

Instruments shall be capable of receiving “near simultaneously” spacecraft generated commands and ground generated commands.

3.5.5.3.4 Spacecraft Memory Loads and Ground Memory Loads

Instruments shall be capable of receiving “near simultaneously” spacecraft generated memory loads and ground generated Memory Loads.

3.5.5.4 Spacecraft/Ground Memory Load Authority

If a ground memory load is received during a spacecraft memory load the instrument shall drop the spacecraft memory load and execute the ground memory load.

3.5.5.5 Spacecraft/Ground Command Authority

Simultaneous receipt of ground terminal generated commands and spacecraft generated commands shall result in both commands being executed.

3.5.5.6 Command/Memory Load Authority

Simultaneous receipt of commands and memory loads shall result in both commands and memory loads being executed.

3.5.6 Telecommand/Memory Load Data Transfer process

a. Each CCSDS packet transfer shall be a separate operation.
b. The first CCSDS packet segment of a CCSDS packet set shall contain the number of CCSDS packet segments in the secondary header per Figure 3.3.3-6. If the command or memory load is a standalone packet, the number of packets field is not used per Figure 3.3.3-10.
c. Command and memory load transfers shall always start with the first subaddress listed for the purpose in Table 3.4.8-1.
d. The instrument shall read this address and determine the number of words (word = 2 CCSDS octets = 16 bits) from the primary header. The number of words is defined as packet length plus one (W +1).
e. The number of subaddresses to be read is defined by $Round\_up\left[\frac{(W+1)}{2} \Big/ 32\right]$.
f. The instrument shall read number of packet segments (P), if more than one is required for the CCSDS packet set, from the secondary header. The number of CCSDS packets to be received is defined by $P+1$.
g. For CCSDS packet sets the instrument shall complete reading the first CCSDS packet and wait for next CCSDS packet that will begin again with the first subaddress as listed in Table 3.4.8-1.
h. A new CCSDS packet shall not begin until the last CCSDS packet is complete.
i. This does not imply a complete CCSDS packet set, only a standalone packet or packet segment.
j. A new CCSDS packet or packet set, using the same APID, shall not be initiated prior to the completion of another CCSDS packet or packet set.
k. The instrument shall be capable of receiving a CCSDS packet set with another CCSDS packet between packet segments using the same APID.
l. The instrument shall be capable of breaking up memory loads into small enough CCSDS packet sets such that it may be accomplished over multiple contacts.
m. The instrument shall detect the initiation of a new CCSDS packet or packet set, using the same APID, prior to completion of another CCSDS packet set.
n. Detection shall cause all packet segments associated with the as yet unfinished CCSDS packet set to be abandoned.
o. Abandoning CCSDS packet segments and or CCSDS packets due to errors shall be indicated in telemetry.
p. The instrument shall be capable of detecting the complete reception of a packet, packet segment and CCSDS packet set by using the header data and counting octets.
q. Note: A command or memory load is only a BC to RT transfer defined in Section 4.3.3.6.1 of MIL-STD-1553B.

3.5.7 Command Constraints

All instrument constraints related to the usage of any sub-address shall be documented in the ICD.

3.6 Time Code Data

Table 3.5.7-1 Time Code Format			
T-Field			
	Day	**msec of Day**	**msec of msec**
Bits	16	32	16
Time Resolution of 1 μsec	0 to (2^{16}-1)	0 to 86,399,999	0 to 999

3.6.1 Time Code Data and Format

All Instances of time code data shall be spacecraft time presented in CCSDS segmented Time Code (CDS) format defined in CCSDS 301.0-B-2 per Table 3.5.7-1. The time code represents spacecraft time at the next Epoch(i.e., at the tone the time will be).

3.6.2 Time Code Data Transfer

The broadcast time of day shall arrive at the instrument between 100ms and 900ms prior to the arrival of the next time of day pulse per Figure 3.6.2-1.
The time code packet shall be broadcast to all RTs over receive subaddress in Table 3.4.8-1.

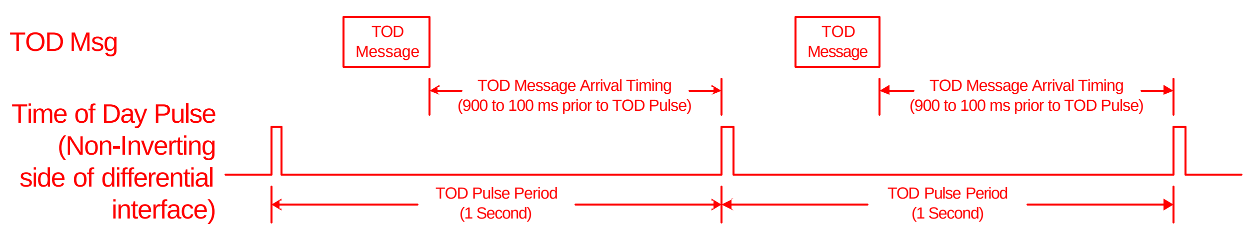


Figure 3.6.2 -1 One Second Time-of-Day Timing

3.6.3 Time Code Effectivity

The broadcast time shall become effective upon receipt of the Time-of-Day pulse that follows.

3.6.4 Time Code Data Epoch

The epoch shall be January 1, 1958.

3.6.5 Missing Time Code Data

The instrument shall be capable of continued normal mode science observations, until transfer to safe mode is effected, if the time code data is not received.

3.6.6 Time-of-Day Uncertainty With Time-of-Day Pulse

The Time-of-Day pulse send in the TOD packet shall correspond to international standard UTC time at the occurrence of the TOD pulse $\pm$ 200 microseconds. The instrument additional time-of-day uncertainty as included in the packet shall be less than 500 microseconds.

3.7 Instrument Data Rates

3.7.1 Total Instrument Data Rate

The total instrument data rate averaged over any one-second period shall not exceed the instrument peak data rate specification and shall be documented in the ICD.
The instrument average data rate shall be defined to be the total data for one orbit divided by the orbit period and shall be documented in the ICD.

3.7.2 Data Packetization

All data shall be packetized using the CCSDS Path Protocol Data Unit (CP_PDU) format as specified in section 3.3.
The size of packets shall not exceed Table 3.3.1-1 . The instrument contractor shall document in the ICD each APID, contents, maximum packet size, peak data rate and average data rate including all packet contents[a], for each instrument mode.
Instrument packet sizes shall include all packet instrument contents.

3.7.3 Instrument Combined Data Bus Rates

					PEAK DATA RATES (Kbps)			
	Polling Rate	1553 Messages	# Words Per SubAdd	Max Words per Poll			Bus Rate	Bus Rate
	Frq	per poll			TLM			w/Retry
Sensor	(Hz)	Each Sample			Specified	Sampled	100% Retry	Total
ATMS	8.00	8	32	256	30.00	32.77	33	66
OMPS	16.00	24	32	768	190.00	196.61	197	394
ERBS	2.00	11	32	352	10.50	11.27	12	24
TSIS	1.00	1	32	32	0.50	0.52	1	2
GPSOS	16.00	25	32	800	200.00	204.80	205	410
ALT	8.00	5	32	160	20.00	20.48	21	42
APS	16.00	17	32	544	135.00	139.27	140	280
SS	16.00	25	32	800	200.00	204.80	205	410
SARSAT	1.00	1	32	32	0.10	0.52	1	2
SESS	1.00	2	32	64	84.00	1.03	2	4

The sensor peak rates shall not exceed the values in Table 3.7.3-1 TBR.

Table 3.7.3-1 1553 Instrument Polled Data Rates (TBR)

3.7.3.1 Telemetry Maximum Rates

The maximum duration of a data transfer cycle (in number of 1553 Messages) and the maximum frequency of polling is reflected in Table 3.7.3-1
Table .

[a] Primary header, secondary header and data field

3.7.3.2 Telecomand Maximum Rates

Maximum telecommand rates shall be limited by the uplink rate, instrument operational constraints and the load requirements of the instrument.
All telecommand and memory load data rate or other operational constraints shall be documented in the ICD.

3.8 Instrument Data Types

Each of the following data types shall employ one or more APIDs as appropriate to allow optimal data extraction to meet EDR performance at each processing terminal[a] including the limiting effects of link bandwidth.

3.8.1 Housekeeping Data

Housekeeping data shall provide status data required for instrument status and health monitoring.
The status data shall include the following:

- Instrument mode, state and configuration
- Temperatures
- Input current for each power supply service
- Output voltage for each power supply service
- Relay status
- Rotational rates of scan mirrors and other rotating mechanisms.
- Other instrument engineering data required to support instrument

3.8.1.1 Housekeeping Data Rate

a. Instrument housekeeping data shall be generated continuously in normal mode.
b. Instrument housekeeping data shall be generated at an orbital average rate not to exceed 2048 bps.
c. Instruments shall generate housekeeping at a peak data rate as averaged over any scan cycle or 1 second period to be less than or equal to 2048 bps or shall meet requirement d.
d. When peak data rate over a 1 second period exceeds 2048 bps the instrument shall be capable of buffering the data so as to prevent data loss when the spacecraft accepts the data at 2048 bps.
e. The spacecraft shall accept data from each sensor at 2048 bps or less.

3.8.1.2 Housekeeping Data Timeliness

The delay between housekeeping data generation and availability for transmission onto the data bus shall not exceed 2 seconds plus the fundamental instrument scan or data production cycle.

3.8.2 LEO&A Data

A pre-defined critical subset of instrument Engineering and Housekeeping data shall be extracted by the instrument and sent to the spacecraft using a dedicated APID.

[a] Terminals incorporate all users of the SMD, HRD and LRD links including field terminals.

Critical Data shall be documented in the ICD.

3.8.2.1 LEO&A Housekeeping Data Rate

Instrument LEO&A packet shall be generated continuously at a rate not exceeding 256 bps

3.8.3 Calibration Data

Calibration data required for Instrument calibration, alignment, and data processing shall be as documented in the ICD.

3.8.4 Dwell Data

Dwell data shall be a specific set of data, as defined in the ICD, requested by command to be repetitively sampled for diagnostic purposes.

3.8.5 Science Data

Science data shall be broken into multiple APID such that the data is capable of being sorted by APID at the lowest useful level.
Science packets shall consist of Instrument measurement and observation data, whether processed or raw, such that the combination of science data and engineering data is, without excess, sufficient to achieve specified performance as determined by the supplier of the associated mathematical algorithms.

3.8.5.1 Science Data Rate

The average and peak science data rates of a Instrument shall not exceed the data rates contained in the Instrument contracted specification.

3.8.6 Diagnostic Data

Instrument diagnostic data shall be any instrument data other than normal engineering data and science data that are down-linked to support ground diagnosis of instrument anomalies.

3.8.6.1 Diagnostic Data Rate

The combined output rate of science data and diagnostic data of an instrument shall not exceed the maximum contract specified data rate of the instrument.

3.8.6.2 Diagnostic Data Transfer

Diagnostic data shall be transferred to the spacecraft via the 1553 bus in the same way science data is transferred. *The same sub-addresses will be used also.*

3.8.7 Engineering Data

Engineering packets shall consist of all data required to meet specified science data processing performance such that the combination of science data and engineering data is, without excess, sufficient to achieve specified performance.

3.8.8 Test Data

Test packets shall be a stand alone 256 byte CCSDS formatted packet containing CChex for each byte of data generated continuously by the instrument processor and sent to the bus controller at science data packet frequency when commanded by the spacecraft.

3.8.9 Telemetry Monitor Data (if necessary)

If a Instrument requires an action by the spacecraft, the Instrument contractor shall supply the appropriate algorithm, to the spacecraft contractor, associated with each data item within a telemetry monitor packet..
Telemetry Monitor packets shall be used to request an action by the spacecraft.
Telemetry Monitor packets shall contain only the information required for the specified action by the supplied algorithm.
All supplied requirements for spacecraft actions associated with telemetry monitor packets shall be documented in the ICD.
All Telemetry Monitor requirements from the Instrument contractor shall be by agreement with the spacecraft contractor.

3.8.10 Memory Dump Data

Memory dump packets shall consist of a range of memory not to include computer register, which could lock up cpu upon register access.

3.9 MIL-STD--1553B Data Packetization

Instrument data shall be packetized using the CCSDS Path Protocol Data Unit (CP_PDU) format (also known as Version 1 Source Packet) as shown in Table 3.3.1-1 and Figures 3.3.3-1 through 3.3.3-5

3.9.1 Content and Structure

Data packets using the same Application Process ID shall have the same contents and structure.
Assigning different Application Process ID's shall accommodate different contents and structures.

3.9.2 Packet Segmentation

The instrument shall segment science data packets longer than 1,024 CCSDS octets before transferring to the spacecraft via the 1553 bus as shown in Figure 3.3.3-1, Figure 3.3.3-2, Figure 3.3.3-3, and Figure 3.3.3–4.
Each segmented packet shall be 1,024 CCSDS octets in length except for the last one or a standalone packet, whose length shall be less than or equal to 1,024 CCSDS octets.

3.9.2.1 Primary Header

3.9.2.1.1 APID

Application Process Identifiers (APIDs) contained in segmented packets shall remain the same throughout all CCSDS packet segments part of the data set being sent.

3.9.2.1.2 Sequence Flag:

The sequence flag for a segmented packet shall follow the following protocol:

- 01 for the first segmented packet

- 10 for the last segmented packet
- 00 for the in-between segmented packets (middle)
- 11 for the standalone packets (un-segmented)

Packets may proceed from first packet to last packet without any middle packets.

3.9.2.1.3 Packet Sequence Count:

a. Packet sequence-count (primary header) in a CCSDS packet shall monotonically increase for all packets of the same APID.

b. The packet sequence count in the primary header in a CCSDS packet shall only be 00 by virtue of a count rollover.

3.9.2.2 Secondary Header

3.9.2.2.1 The secondary header shall only exist for the first packet of a segmented CCSDS packetized data set and a standalone packet except TMON and LEO&A packets.

3.9.2.2.2 Time of Day

a. The first 8 octets of the secondary header shall be the Time-of-Day derived from the time data broadcast by the spacecraft.
b. The Time-of-Day shall be coincident with the time of creation of the first data within the data field.
c. The Time-of-Day shall employ the format in section 3.6.1.

3.9.2.2.3 Number of Packet Segments

The ninth octet of data in the secondary header shall be the number of packet segments field containing the total number of packets expected for this CCSDS packet set minus one.
The tenth octet of data in the secondary header shall be spare bits.

3.10 Instrument Telemetry Data Transfer Process

The spacecraft bus controller (BC) shall control the transfer of instrument telemetry data by conducting a sequence of reads employing RT-to-BC transfers defined in Section 4.3.3.6.2 or RT-to-RT transfers (instrument RT to spacecraft RT) defined in Section 4.3.3.6.3 of MIL-STD-1553B using specified instrument RT transmit sub-addresses and the following protocol:

a. At the maximum predefined intervals ($1/Polls\ per\ second$) in
b. Table each instrument shall load its telemetry data (1553 message set) up to the maximum (1553 Messages in
c. Table) into the predefined transmit sub-addresses, in Table 3.4.8-2, and update its Data Ready Indicator (DRI).
d. If the 1553 message set contains multiple CCSDS packets and or CCSDS packet segments to be sent during one polling period, no gaps shall exist between any of the CCSDS Packets and or CCSDS Packet Segments as the data is loaded into the 16 subaddresses each containing 32 words of 2

CCSDS octets each through the repetitive cycling of these subaddress until the total 1553 Message Set has been sent.

At the appropriate interval, per the polling period in

e. Table , for each instrument, the BC shall instruct the instrument to transmit its DRI from transmit sub-address 29 which consists of a single data word.
f. The DRI shall contain the total count of 16 bit data words in the data-set to be read.
g. If the indicator is zero, the BC shall takes no further action until it is time to poll the instrument again.
h. If the indicator is non-zero, the BC shall instruct the instrument to transmit its data by performing reads of Table 3.4.8-2 subaddresses starting with the first subaddress and incrementing the subaddress number as required to retrieve the number of words indicated by the DRI word.
i. If there are more words to be transmitted than are allowable within the Table 3.4.8-2 subaddresses, at thirty-two (32) sixteen (16) bit words for a total of sixty-four (64) CCSDS octets per subaddress, the BC shall repetitively cycle through the subaddresses repetitively each time starting at the first subaddress until the total 1553 message set is transmitted.

Note: Each read transfers 64 CCSDS octets of data to the spacecraft.

j. Following the data transfer of the data set, the BC shall write, End of Data Transfer Cycle, a 16-bit word to the instrument's receive sub-address 29 to indicate to the instrument that the data transfer has been completed. The data value written to receive sub-address 29 is an echo of the instrument's DRI.
k. The instrument shall subtract the number of words sent from the DRI value. If the DRI had not incremented, indicating addition of more data, during the just completed data transmission, the value shall be zero.

Note: A write is either a BC to RT transfer defined in Section 4.3.3.6.1 or a RT to RT transfer (spacecraft RT to instrument RT) defined in Section 4.3.3.6.3 of MIL-STD-1553B.

3.10.1 Instrument Telemetry Data Sampling Rate

The rate at which the spacecraft polls a instrument to collect telemetry data shall comply with instrument engineering data requirements and shall be documented in the ICD.

3.10.1.1 Instrument Telemetry Data Rate

The instrument peak data rate of transfer shall be as defined in section 3.7.3.

Note: This includes science data, housekeeping telemetry, memory dumps, and diagnostic data.

3.10.1.2 Instrument Telemetry Buffering

The instrument shall provide buffering for those periods of time where the data rate of transfer is above the average described in section 3.10.1.1.

3.10.1.3 Deleted

3.10.2 Instrument Telemetry Data Transfers

A single transfer of data shall be comprised of one or more whole packets.
The maximum number of packets to be transferred for each sampling interval shall be the same.
Packet transfers shall not use fill between individual packets or to complete a 1553 transfer.

3.10.2.1.1 Transfer Size

3.10.2.1.2 Inter-1553 Message Gap

The bus controller shall provide a minimum gap time of 4.0 microseconds between sub-addresses as shown by "T" in Figure 3.10.2-1.

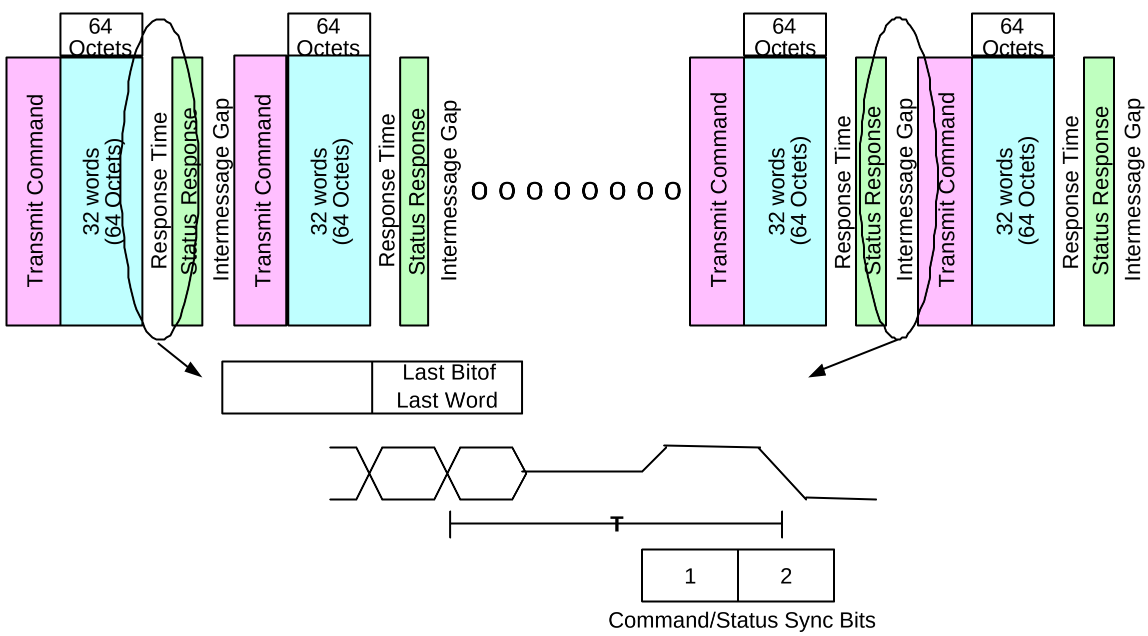
3.10.2.1.3 Transfers Exceeding the Sub-address Space

For multiple consecutive 1553 Message that exceed the number of available sub-addresses, once the last available sub-address has been used the sub-address sequence shall be restarted after a minimum delay of 4.0 microseconds (inter-1553 Message gap) as determined by the bus controller.

3.10.2.1.3.1 Multiple CCSDS Packets Via a Single 1553 Transfer

Multiple CCSDS packets transported via 1553 shall concatenate the CCSDS packets per Figure 3.10.2-2.
No fill data shall be inserted to complete a 64octet subaddress transfer.
No inter-1553 Message gap shall be inserted unless the last 1553 Message completed the subaddress transfer.

3.10.2.1.4 Timing



The timing of packet transfers via the bus shall be as shown in Figure 3.10.2-1.

Figure 3.10.2-1 Packet Transfer Timing

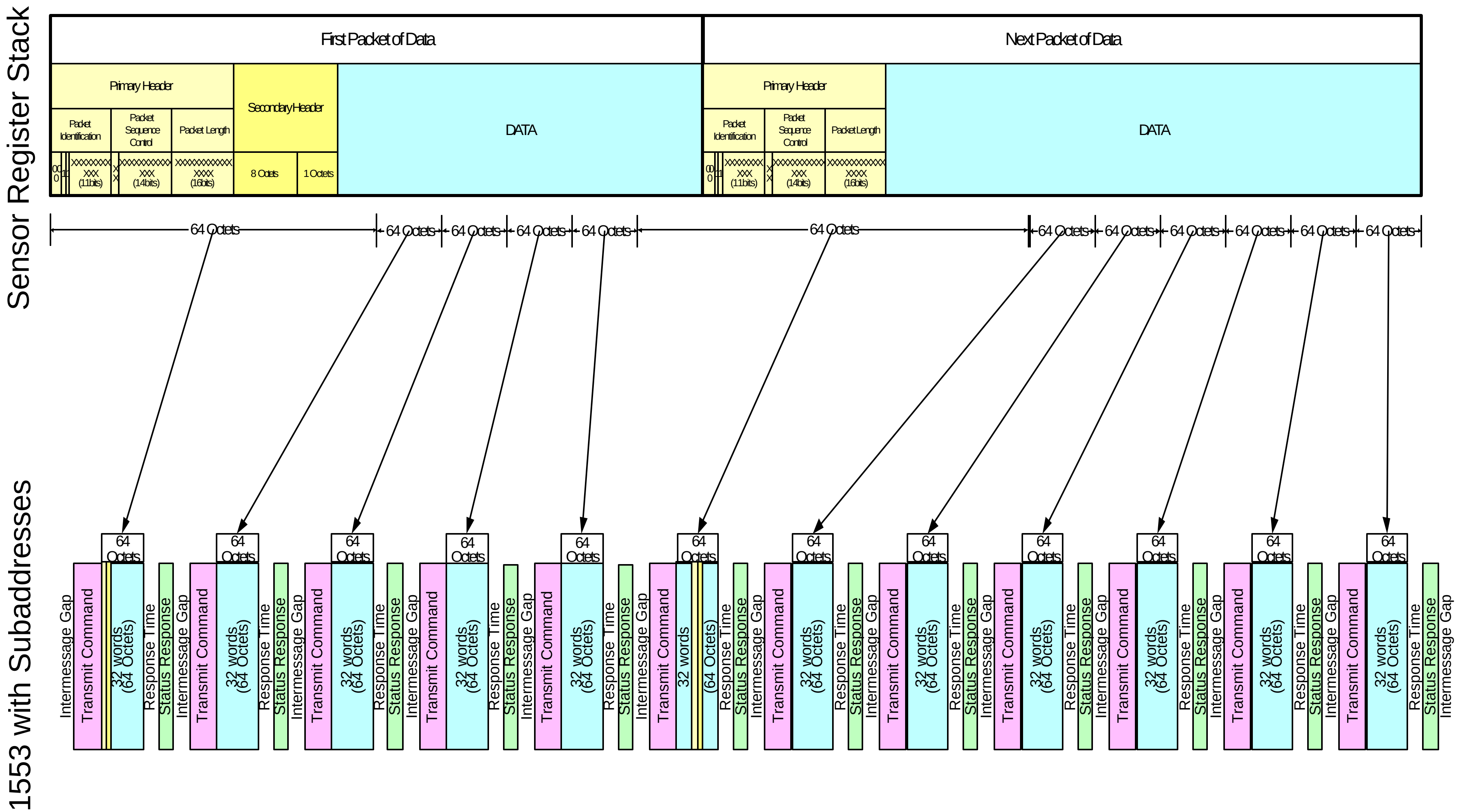


Figure 3.10.2-2 Multiple Packets Within a Single 1553 Transfer

3.10.2.1.5 Response Time

The RT shall respond to a valid command word within the time range of 4.0 to 12.0 microseconds as shown by “T” in Figure 3.10.2-1.

3.10.2.1.6 Time Out

A 1553B remote terminal shall implement an automatic time-out.

3.10.2.1.6.1 Time Out Effect on End of Data Transfer Cycle

In the event the spacecraft fails to signal the End of Data Transfer Cycle to the instrument, this time-out signal shall be functionally equivalent to the End of Data Transfer Cycle, Section 3.10, signal to prevent disruption of data transfer and instrument operations.

3.10.2.1.6.2 Time Out Delay

The minimum time a remote terminal or bus controller shall wait before considering that the response has not occurred shall be 20 microseconds as shown by “T” in Figure 3.10.2-1.

3.11 Connectors

3.11.1 Part Number

The instrument shall use Sabritec connectors, part number 015728-5001, or specify in their ICD the specific connectors used and supply two sets of mating connectors per instrument delivered plus two sets for the construction of test cables.

3.11.2 Pin Assignment

3.11.2.1 Triaxial Connectors

The center wire of triaxial connectos shall be signal plus (+).
Where color-coded wire is used the color for this wire shall be blue with the minus (-) wire white.

3.11.2.2 Non-Triaxial Connectors

Non-triaxial connector pin assignments shall be such that twisted shielded wire pin spacing facilitates attachment.
The connector shall not be shared with any other function.
Color-coded wire shall be used. The color for this wire shall be blue for positive (+) and white for minus (-).

3.11.3 Connector Designators

Each connector shall be labeled PJ1, PJ2, RJ1, or RJ2 where the “P/R” represents the prime or redundant instrument electronics and the “1/2” represents the prime or redundant 1553 bus to be attached.

4 DEFINITIONS

4.1 Acronyms and Abbreviations

This section contains an alphabetical list of all of the abbreviations and acronyms used in this document.

Acronym	Definition
APID	Application Process Identification
BC	Bus Controller
CCSDS	Consultative Committee for Space Data System
CDS	CCSDS Day Segmented Time Code
DRI	Data Ready Indicator
EDR	Environmental Data Record
FSW	Flight Software
GIID	General Instrument Interface Document
ICD	Interface Control Document
ILL	Interrupt Log List
IRD	Interface Requirements Document
LSB	Least Significant Bit
Mbps	Mega bits per second
MSB	Most Significant Bit
RDR	Raw Data Record
RT	Remote Terminal
SC	The NPOESS Spacecraft

4.2 GLOSSARY

Byte:	The computer term for eight (8) digital data bits.
Data Set:	Multiple packets or packet segments during a single transfer.
Chunk:	A contiguous set of bits, not CCSDS formatted.
Epoch	The point in time, represented by a pre-specified indicator, where an event is to occur or data is to become effective.
1553 Message:	A 1553 message is comprised of up to thirty-two (32) each sixteen-bit (16) bit words or the maximum contents of one 1553 subaddress.
1553 Message Set:	The complete set of 1553 messages (subaddress contents) required for the transfer of 1 or more CCSDS packets and or CCSDS packet segments.
CCSDS octet:	The CCSDS term for eight (8) digital data bits also known as a byte.
CCSDS Packet:	A single CCSDS formatted chunk of data that may be complete unto itself or a part of the total Data Set to be transferred.
CCSDS Packet Set:	The total set of packet segments (always more than one) in a CCSDS formatted data transfer where the data is larger than a single packet permits.
CCSDS Packet Segment:	A CCSDS formatted chunk of data that requires other packet segments to compete the packet set.
Segmented	Data subdivided into multiple CCSDS packets, called CCSDS packet segments, thus comprising a CCSDS packet set.
Packet Segment	A single packet part of a larger CCSDS packet set.
Tuple:	A tuple is an ordered set of arbitrary length.
Word:	The computer term for sixteen (16) digital data bits or two (2) bytes or two (2) CCSDS octets.
Network Byte Order:	The order in which the bytes of a word are transmitted. For a 32-bit word; O1, O2, O3, O4, where O1 is the most significant CCSDS octet, O1 is transmitted first, O2 next, then O3, and finally O4. The same applies for any modulo 8-bit tuple.
Near Simultaneous	Near simultaneous means that multiple things occur in-time within a period shorter than the execution time of any of the individual items. Where there is a single serial port it might refer to having a second packet set input begin before the first has completed execution. It may also mean that multiple input APIDs packet sets may arrive together with individual packet segments arriving randomly related to the APIDs until all packet sets are received.